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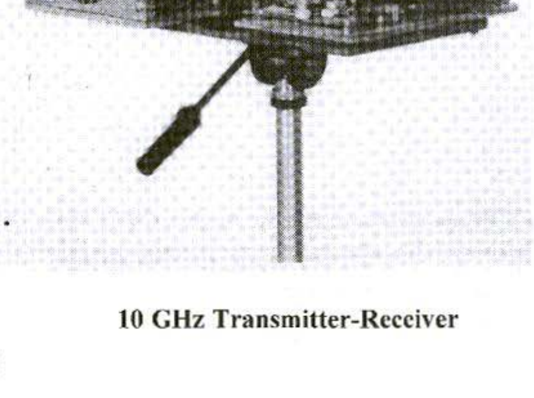
A 10 GHz Super-Regenerative Receiver

1. INTRODUCTION

In 1996 when you are hearing people talking about super-regenerative reception, you think they are old hams regretting their young days! However this kind of reception is still much used professionally: millions of units a year are produced for miscellaneous applications as remote control, supervision, alarms, medical apparatus, etc., with contributions of new techniques as surface resonators (SAW) and up-to-date semiconductors. Indeed, very simple and low consumption devices are valuable for those applications.

We have shown recently [1] that super-regeneration could be still useful for amateurs. Without wishing to compete with conversion reception, results up to 1296 MHz, are not uninteresting as you can see in table 1.

We are going to discover that super-regeneration can be also useful at SHF at 10 GHz.



10 GHz Transmitter-Receiver

		144 MHz	432 MHz	1296 MHz
CW	MDS	150nV	200nV	300nV
	with BFO			
	S/N=10dB	600nV	1mV	1.3mV
AM	MDS	150nV	300nV	300nV
	S/N=10dB	1V	1.5mV	1.5mV
Bandwidth		50 kHz	150 kHz	500 kHz

Table 1: Measured Sensitivities of VHF and UHF Receivers

2.
A REVISION of THEORY

A super-regenerative detector is based on the repeated build-up and decay of oscillation in an oscillator, which is caused to operate intermittently by means of a quenching signal supplied from a separate low frequency oscillator, or from a low-frequency relaxation of the oscillator itself. Those two modes are respectively called "separated quenching" and "self-quenching". After each quenching, during the starting and the build-up of oscillation, the device shows successively a positive resistance behaviour, then zero and finally a negative resistance. When the negative resistance is reached the device is oscillating. But during the period of the exponential build-up of oscillation, it shows a tremendous amplification of up to one million! When no external signal is present at the input the amplification applies to the basic noise. Demodulation of the HF wave, or using the audio or video component in the device producing the negative resistance gives an amplified noise. In phone you can hear the typical and well known rushing sound called hissing or mush-noise. If a signal at the oscillator frequency is applied, the oscillation is started in advance as the starting level of the exponential is higher than the noise alone. This advance gives an increase of the current oscillator, proportional to the signal, but highly amplified.

In the beginning the electronic tube was used as oscillator, but now evidently it is the transistor. Nevertheless, other components are able to produce a negative resistance, for example the unijunction transistor and the tunnel diode. Also, and it was at 10 GHz already, during the Forties, a 723 A/B Klystron [2] showed a 150 uV sensitivity! At that time during World War II an intensive use of super-regenerative devices in VHF and UHF was made by both Allied and German forces, IFF for example.

The final super-regeneration purpose is of course the reception of modulated signals. CW demodulation is very simple, as the transistor current increases when a signal is on, seeing that the oscillation starting is advanced. For AM that current varies as the carrier magnitude. BLU needs a re-established carrier as shown in [1].

FM demodulation is obtained by detuning the SR at one slope of its selectivity curve. Owing to the relatively poor SR selectivity, bad demodulation is obtained with NBFM. But at 10 GHz it is frequent practice to use a much larger modulation, for example with Gunn diode transmitters. Under these conditions FM reception is possible with a poorer quality. A much more correct demodulation could be obtained with a more sophisticated device, but we do not make HI-FI and it is workable. Phone tests were done, that by means of audio signals; it could be possible to demodulate video with a sufficient quenching frequency. Shannon will remember us to increase the quenching frequency to at least twice the highest signal frequency !

3. CIRCUIT DESCRIPTION

For this 10 GHz device (3 cm wavelength), it was considered to use the self-oscillator ATV transmitter described in [3].

A lack of frequency stability was stated for phone work at the various ambient temperatures, especially in portable conditions. So, a more efficient solution using a dielectric stabilised oscillator has been retained. We can make this DRO [4], [5], [6], [7], [8], but it is easier to find it free! Indeed you can find LNBs in antenna shops: out of use LNBs because the DRO is not often considered reusable, or LNBs replaced by a more up to date device. A professional directory, a telephone, a bit of patience and you are able to find those LNBs, in order to check and then modify them.

As the DRO is used as the local oscillator its frequency varies upon the received frequency range and the intermediate frequency. Usual frequencies are 9.75, 10 and 10.475 GHz. As the phone traffic is usually done at 10.368 GHz, we need to shift the DR frequency.

As shown in the above-mentioned articles you can increase the frequency by abrasing the DR with sandpaper to decrease its height, or to increase it by adding a piece of ceramic in order to lower the frequency. Our attempts showed up better using the first method in preserving the relatively low temperature coefficient. On the contrary, adding a piece of ceramic impairs the stability. Indeed to sufficiently lower the frequency needs a great thickness of low permittivity ceramic adding; on the contrary if the permittivity is high, the thickness will be lower but the ceramic temperature coefficient is very high usually. In both cases the DR original coefficient will be modified and the DRO frequency will drift off several megahertz for indoor temperature variations and a far too much for portable use. An answer is to use a piece taken from an another DR which is sacrificed for that.

The overall DRO temperature coefficient depends not only on the DR but also on the case dilatation, adjustment screw and transistor parameters. An equalisation has been reached by the

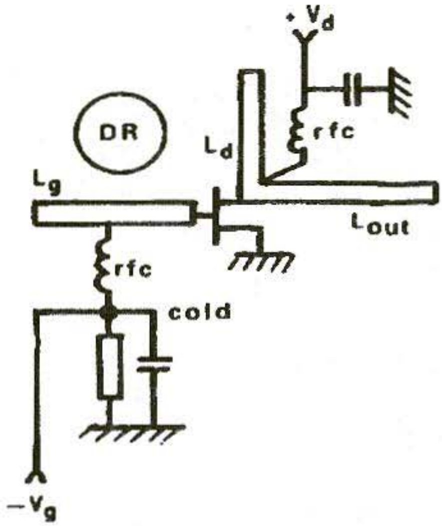


Fig.1: DRO with Gate side cold point

manufacturer and the balance could be upset by our modifications, and then damage the stability. Moreover, those modifications do not have to bring the

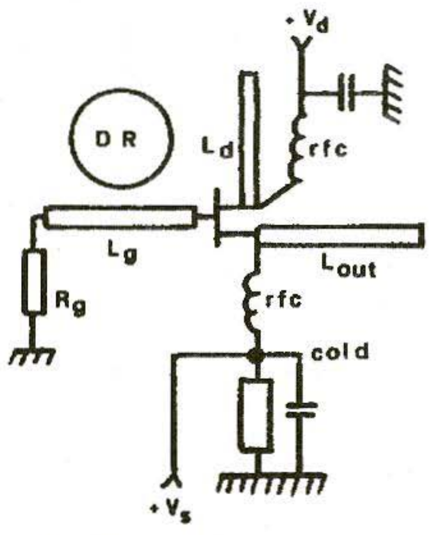


Fig.2: DRO with Source side cold point

screw nearer to the DR as the Q factor would be weaker, which means increased losses and gives a more stringent adjustment.

It is profitable to carry out one or two ageing cycles after a DRO modification in order to stabilise components which were mechanically stressed and require a stable state. That could be obtained by a one hour curing in an oven at 40° Celsius. The oldest LNBs which are the most available have a 9.75 GHz local oscillator. It is very easy to shift them to 10.368 with only a little patience [5].

Making a self-quenching super-regenerator with a DRO requires the addition of a resistor into the drain circuit to pick-up the audio signal and to produce the quenching oscillation. Gate-source voltage control will state the operating point, which is quite critical, to obtain the highest super-regenerative sensitivity. Several configurations are used for DR0 as with all kinds of oscillators.

The DR can be placed gate side, drain side, between gate and drain, etc. Some experiment showed it is possible to make them generally working as SR more or less easily. But two cases appear to inject the gate-source voltage at an originally cold point to avoid a DRO modification. Upon the instance a negative voltage will be injected gate side or a positive voltage source side. Figures 1 and 2 show typical diagrams for both cases. That voltage is brought through a 0.8 mm hole very close to the cold point.

An audio amplifier is all that is required after the SR with a low-pass filter in order to remove the quenching frequency, which could disturb the ampli-

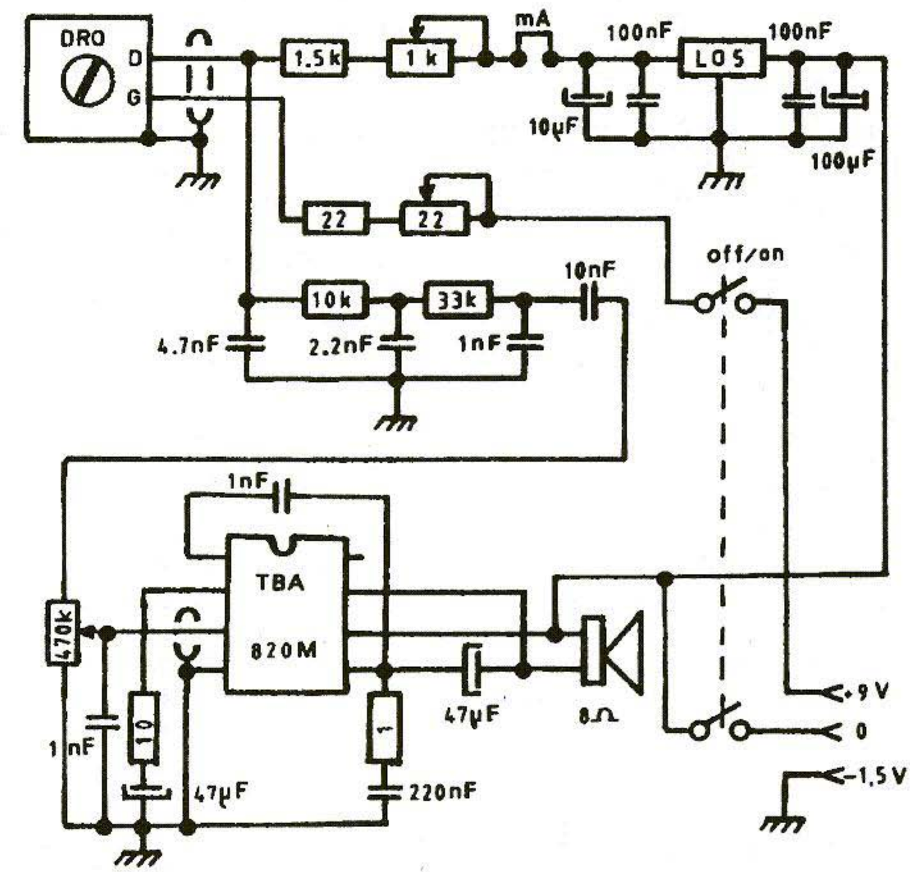


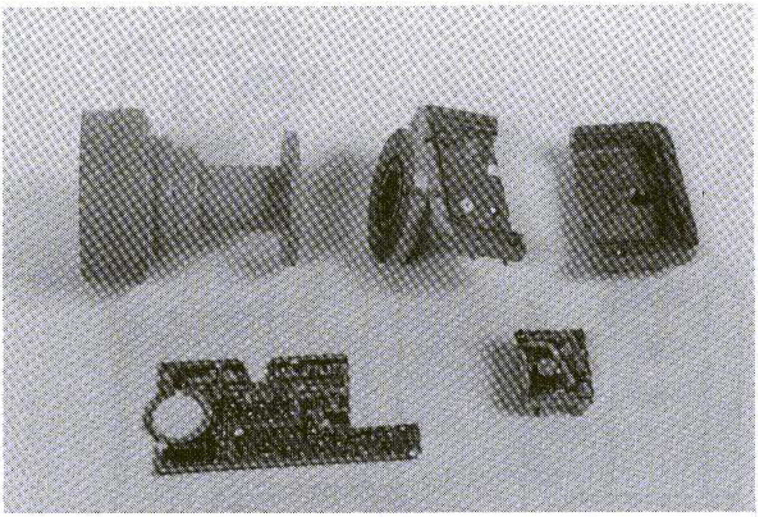
Fig.3: 10 GHz Regenerative Receiver

fier even into inaudibility. A regulated power supply is needed for the DRO as its frequency varies appreciably with the supply voltage. For an oscillator the drift is about 1 to 2 MHz per volt in the 4.5 to 5 volts range.

Figure 3 shows the complete diagram. The DRO used required a negative voltage gate-source so a 1.5 V battery has been added to the two 4.5 V batteries for the positive supply.

4. CONSTRUCTION

The photograph and figure 4 show the layout. At first you have to separate the DRO from the LNB by sawing out the case, screens, printed circuit, etc. That gives a small screened box with the original screw for frequency adjustment. After that, the DRO is placed against a



10 GHz LNB sawn into its component parts

waveguide WR90/R100 in which a slot has been made. That slot lets into a small piece of Teflon insulated wire (a 5 millimetre coaxial cable with removed braid) connected at the DRO output. The slot allows the DRO to be installed at the optimum place, slides with blocking screws or a rubber ring are used to fix it in position.

Two setting screws have be provided in order to round off the impedance matching. The DRO original screw will allow you to tune the SR at the wanted frequency, for example 10.368 GHz.

A small piece of ball pen body is glued to the bolt head to make the adjustment easier. The waveguide is attached through a flange to a 20 dB horn made in epoxy-glass as sized in [9].

5. MEASUREMENT RESULTS

Measurement was carried out with the following equipment:

- Tektronix 465 oscilloscope to show the quenching wave
- Hewlett-Packard 141T spectrum analyser with 8555A 18 GHz rack and 8552B IF rack
- frequency meter made of a new LNB with 9.75 GHz LO in front of a 2.4 GHz frequency meter. Although all of the various filters are not tuned on the input and the intermediate frequencies, sensitivity is enough for frequency measurement

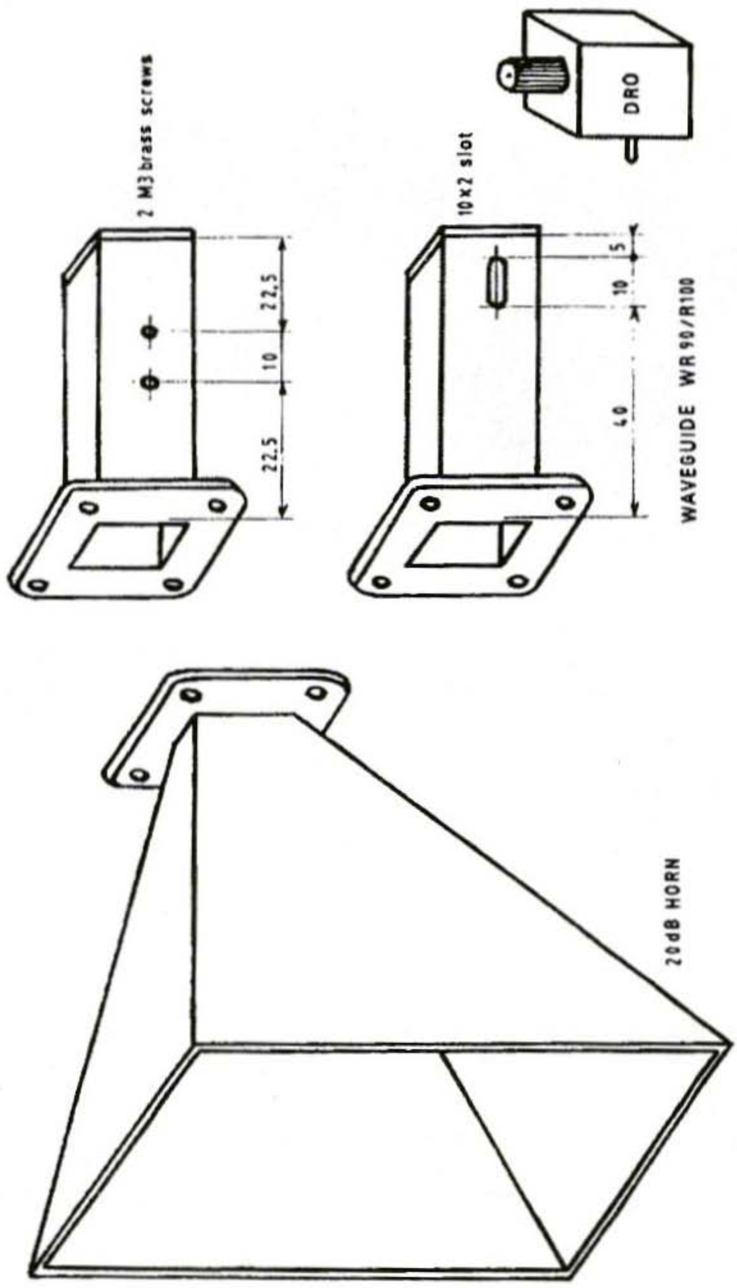


Fig.4: Mechanical design including waveguide front and rear views

- 2.4 GHz frequency meter with a 12 GHz pre-scaler as describe in |10|
- Polarad G711 hyper frequency generator tunable from 6.950 to 11 GHz. That equipment is too old to allow sensitivity measurement at the current levels as its leakage is enough to insure reception at several meters! It was necessary to place the generator in a separate room, to use a coaxial cable connection and to add an extra attenuator
- Yupiteru receiver, wide coverage from 430 kHz up to 1650 MHz, connected to LNBs for comparative sensitivity measurement
- two DROs settled around 10.368 GHz, frequency modulated. Settings and measurements are the following.

The drain current is settled by both gate-source polarisation and variable resistance in the drain circuit. SR behaviour is insured in average from 0.8 to 2mA upon the components DRO characteristics. There is no super-regenerative action below, but only regeneration. Above the device is always oscillating without usable reception.

The maximum sensitivity is obtained barely beyond the hissing appears. Quenching frequency increases as for any kind of self-quenching SR proportionally to the fixed drain current and when the received signal is growing. The selected values gives a frequency of about 20 to 200 kHz. Figure 5 gives the wave form at the drain cold point.

The SR bandwidth depends on the quenching frequency (to see the level up reference [1]). Selectivity measurement confirmed that statement and gave from 150 kHz to 2 MHz upon the setting. That measurement was done by two unmodulated DROs as shift frequencies generators. To give information, the SR radiated spectrum is shown by figure 6. It is similar to the pulse radars one [12], but asymmetrical as the train of waves growing and decreasing are different. Our measurement resources did not allow us to work out absolute sensitivity values. But comparisons were done between different equipments.

Even with the dubiousness of measurement, SR shown a sensitivity practically alike to a classical conversion receiver using a IN23 diode, an Gunn diode as LO, a FI of about 85 MHz and a frequency demodulation. That receiver was pro-

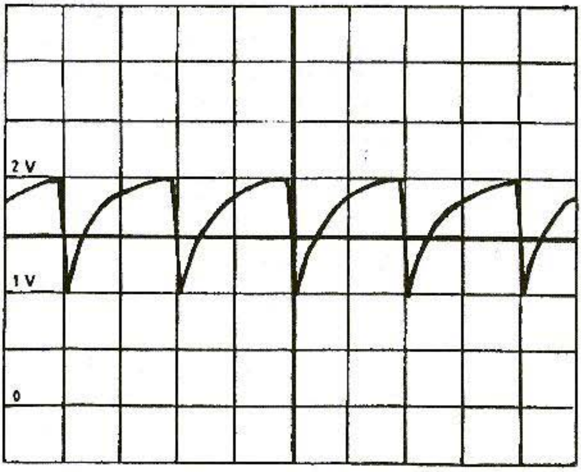


Fig.5: Drain Cold Point Waveform

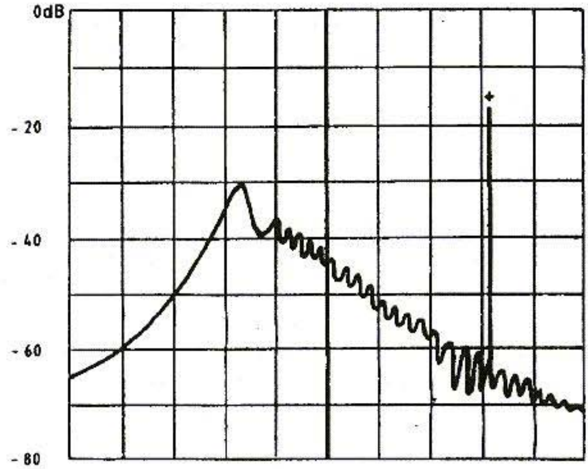


Fig.6: Supr-regenerative Receiver Spectrum
Scan width: 2 MHz/div
Scan time: 0.5 s/div
Bandwidth: 10 kHz

+ received signal added to spectrum at the analyser input

vided with the same 20 dB horn as for the SR.

An LNB followed by the Yupiteru receiver shows a very variable sensitivity as the case may be. If the input and output filters have been modified the sensitivity is much better, which is not surprising owing to the premium transistors used on the 10 GHz side.

With an unmodified LNB with a 9.75 GHz LO, the sensitivity is better than the SR one. On the contrary, for an unmodified LNB with a 11.475 GHz LO, the sensitivity is very poor as the filters are too far from the needed frequencies.

6. SUCCESSFUL CONTACTS

Table 2 gives an extract of the F9HX's log book concerning worked contacts at 10 GHz by that time of writing. It shows that it is possible to make contacts in receiving conditions we were expecting from sensitivity measurements. It is not great DX but by proper paths one certainly could do much better. In all cases the receiver was the one described here. When the correspondent had got a receiver, a two-way contact was established with an F9HX/P transmitter comprising a FM modulated DRO and a 20 dB horn as for the receiver. All communications were done in or nearly in sight. It is certainly possible to make contacts by reflection, refraction and/or diffusion as is readily done, but it was not carried out before writing this article.

7. CONCLUSIONS

As it was computed in the article conclusions [1], the 10 GHz SR work was easily obtained. Obviously results are not those of a 10 GHz modified LNB for the ham band, but they are

Date 1996	Call	QTH JN25	ASL (m)	TX	Mod	QTH JN25	ASL (m)	QRB (km)	QRK 0-5	QSO
15/08	F1IFI/P	MS	202	DRO	1 kHz	MS	202	1	2	--
28/08	F1IFI/P	MS	206	DRO	1 kHz	MS	264	3.1	5	--
31/08	F1CDT	MR	234	GUNN	PHONE	MR	234	0.1	5	YES
07/09	F1IFI/P	LS	200	DRO	1 kHz	LT	310	6.1	5	--
07/09	F1IFI/P	LS	200	DRO	1 kHz	MS	264	7.5	5	--
12/09	F1FDY	JT	330	DRO	PHONE	MS	264	20	5	--
13/09	F1CDT	MR	234	GUNN	PHONE	MR	234	4	1	--
18/09	F1CDT	MR	234	GUNN	PHONE	LR	230	5.1	5	YES
19/09	F1CDT	MR	234	GUNN	PHONE	IO	318	25.6	4	YES
27/09	F1CDT	MR	234	GUNN	1 kHz	GJ	1250	48	0/3*	YES

Output power in all cases +20dBm; * with QSB

Table 2: Extract from F9HX's log showing some successful contacts

very close to those obtained with a converter using a 1N23 diode as mixer and a Gunn diode as LO. It is certainly possible to obtain a better sensitivity for the device as only a few trials were done for impedance matching

between the DRO and the waveguide. Output DRO is probably not the best input for the signal. A very low noise transistor (less 1dB at 10 GHz), as used at the LNB input, would be surely better than the DRO one as its purpose is to deliver enough power to the mixer. More, FM demodulation by detuning is not very efficient. With AM, result would be much better. But, who is doing AM anymore? The chief interest lies in simplicity and low cost of implicated means: only one transistor and an audio amplifier! Nevertheless you cannot minimise the need for a good theoretical and practical SHF knowledge because great difficulty is on the way to get a result. So, an attempt to use the same DRO to make a transceiver is not yet successful: a significant frequency deviation is stated between RX and TX owing to the transistor drain current and gate-source polarisation differences. We need to compensate that frequency deviation by a varicap acting on a DRO coupled line. Professionally, there are interesting references but the achievement seemed to be difficult for us if we want to have both power to transmit and sensitivity to receive. Therefore wait and we will speak about it again. For the most audacious, there is an open way for experimentation at higher frequencies: 24, 47, 76 145 and 241 GHz (241 GHz that means 1.2 millimetre wave-length!). Indeed, components will probably be accessible for astute amateurs owing to the advent of radars used in luxury cars for protection against running into things whilst reversing, as those equipments are working above 50 GHz.

F9HX would like to show especially gratitude to FICDT thanks, for his competent and devoted help for test, measurement and QSOs.

E and OE!

8. REFERENCES

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